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(54) **CONTROL SYSTEMS AND METHODS FOR MARINE ENGINES EMITTING EXHAUST GAS**

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(52) **U.S. Cl.**
CPC ***F02D 41/1495*** (2013.01); ***F02D 41/1494*** (2013.01); ***F02D 41/1496*** (2013.01)

(58) **Field of Classification Search**
CPC F02D 41/1494; F02D 41/1495; F02D 41/1496
USPC 701/107; 123/688, 690
See application file for complete search history.

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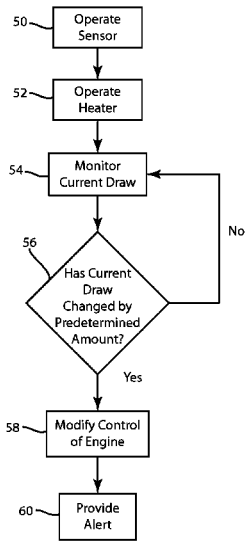
(57) **ABSTRACT**

Control systems and methods are for a marine engine emitting exhaust gas. A sensor senses a characteristic of the exhaust gas. An electrical heater heats the sensor. A control circuit monitors current drawn by the heater. The control circuit controls an operational characteristic of the engine based upon the characteristic of the exhaust gas and modifies its control of the operational characteristic of the engine when the current drawn by the heater changes by a predetermined amount.

20 Claims, 3 Drawing Sheets



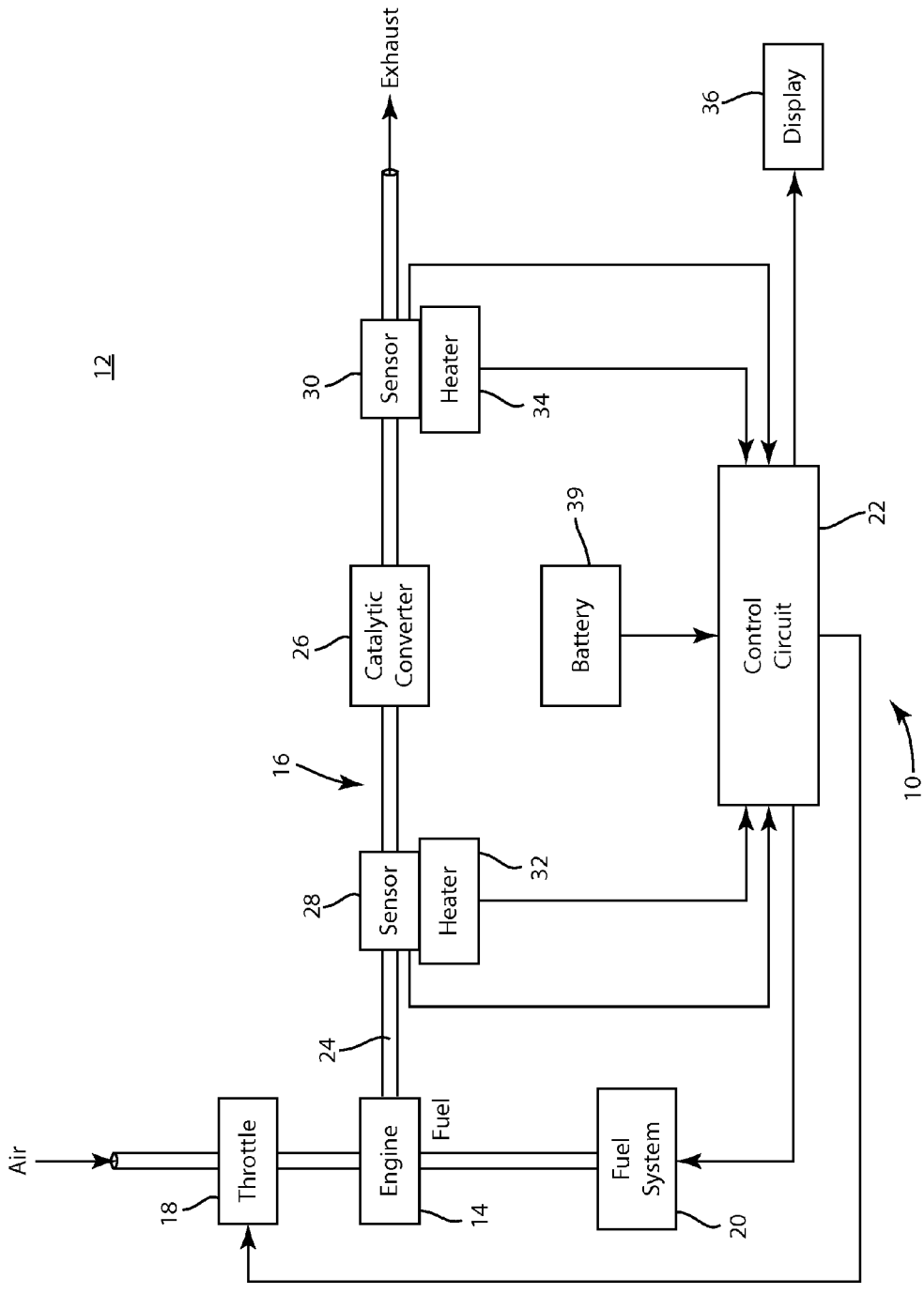

12
Exhaust
36
Display
30
Sensor
Heater
34
39
22
Catalytic Converter
26
Battery
Control Circuit
16
10
28
Sensor
Heater
32
24
Air
Throttle
Engine
Fuel
Fuel System
18
14
20

Fig. 1

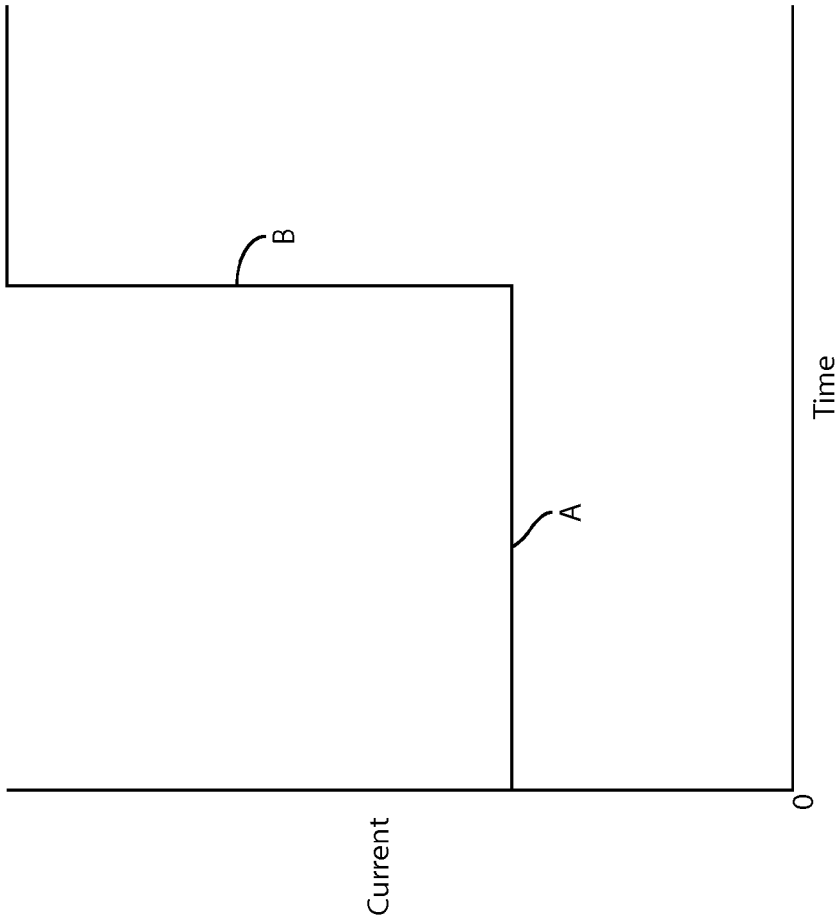


Fig. 2

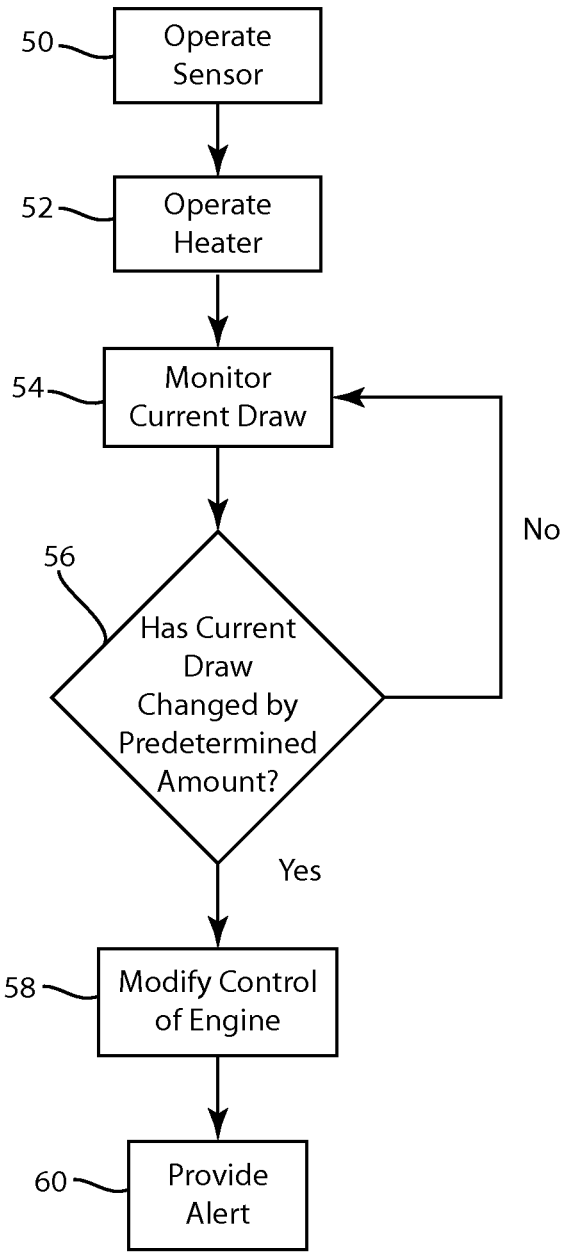

50
Operate Sensor
52
Operate Heater
54
Monitor Current Draw
56
Has Current Draw Changed by Predetermined Amount?
No
Yes
58
Modify Control of Engine
60
Provide Alert

Fig. 3

CONTROL SYSTEMS AND METHODS FOR MARINE ENGINES EMITTING EXHAUST GAS

FIELD

The present disclosure relates to marine engines and particularly to control systems and methods for exhaust apparatus on marine engines.

BACKGROUND

U.S. patent application Ser. No. 13/316,164, filed Dec. 9, 2011, which is incorporated herein by reference in entirety, discloses marine engine exhaust systems that include an exhaust conduit conveying engine exhaust gas from upstream to downstream, a sensor sensing oxygen content of the exhaust gas in the conduit, and a shield located in the conduit.

U.S. Pat. No. 7,552,586, which is incorporated herein by reference in entirety, discloses a marine engine exhaust system having an oxygen sensor located within a catalyst housing structure and downstream from a catalyst device.

U.S. Pat. No. 7,467,628 discloses a control system for an oxygen sensor heater. The control system includes a passive heater control module that generates a heater control signal at a first duty cycle and measures a resistance of the oxygen sensor heater. An exhaust gas temperature mapping module maps the resistance to an exhaust gas temperature. An active heater control module generates a heater control signal at a second duty cycle based on the exhaust gas temperature.

SUMMARY

This summary is provided to introduce a selection of concepts that are further described below in the detailed description. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used as an aid in limiting the scope of the claimed subject matter.

In some examples, control systems for a marine engine emitting exhaust gas comprise a sensor sensing a characteristic of the exhaust gas; an electrical heater heating the sensor; and a control circuit that monitors current drawn by the heater. The control circuit controls an operational characteristic of the engine based upon the characteristic of the exhaust gas. The control circuit modifies its control of the operational characteristic of the engine when the current drawn by the heater changes by a predetermined amount.

In other examples, methods of controlling a marine engine comprise operating a sensor to sense a characteristic of exhaust gas emitted by the engine; operating an electrical heater to heat the sensor; monitoring current drawn by the heater; controlling an operational characteristic of the engine based upon the characteristic of the exhaust gas; and modifying control of the operational characteristic of the engine when the current drawn by the heater changes by a predetermined amount.

BRIEF DESCRIPTION OF THE DRAWINGS

Examples of methods and systems for controlling shift in marine propulsion devices are described with reference to the following drawing figures. The same numbers are used throughout the drawings to reference like features and components.

FIG. **1** schematically depicts a control system for a marine engine emitting exhaust gas.

FIG. **2** is a graph depicting current drawn by a heater over time.

FIG. **3** is a flow chart illustrating one example of a method of controlling the marine engine shown in FIG. **1**.

DETAILED DESCRIPTION OF THE DRAWINGS

In the present description, certain terms have been used for brevity, clearness and understanding. No unnecessary limitations are to be inferred therefrom beyond the requirement of the prior art because such terms are used for descriptive purposes only and are intended to be broadly construed. The different methods and systems described herein may be used alone or in combination with other methods and systems. Various equivalents, alternatives, and modifications are possible within the scope of the appended claims.

FIG. **1** depicts a control system **10** for a marine vessel **12**. The control system **10** is configured to control operational characteristics of a marine engine **14**, which in the example shown is an internal combustion engine that powers a marine propulsor (not shown) such as one or more propellers, impellers, pod drives, and/or the like. The combustion process carried out by the engine **14** produces exhaust gas, which is emitted to an exhaust system **16**. More specifically, flow of air into the engine **14** for combustion is controlled by a throttle **18**. Flow of fuel into the engine **14** for combustion is controlled by a conventional fuel system **20**, including for example one or more injectors and/or the like. Throttles for controlling air flow to an internal combustion engine are within the ordinary skill of the art and therefore are not further herein described. Fuel systems for controlling fuel flow to an internal combustion engine are within the ordinary skill of the art and therefore are not further herein described. The exhaust gas flows from the engine **14** through the noted exhaust system **16** prior to discharge from the marine vessel **12**. The exhaust gas is treated in the exhaust system **16**, as described further herein below, and then emitted to atmosphere.

A control circuit **22** controls operation of the throttle **18** and fuel system **20** based upon various sensed characteristics of the exhaust gas and optionally according to operational characteristics of the marine engine **14**. The control circuit **22** includes a programmable processor and a memory for receiving, processing and emitting electronic control signals via respective communication links to components of the system **10**. The communication links are shown in solid line format in the drawings and can comprise wire and/or wireless links.

The exhaust system **16** includes an exhaust manifold **24**, through which exhaust gas is conveyed to a catalytic converter **26**. Catalytic converter **26** controls emissions from the exhaust system **16** by for example altering rate of oxidation of hydrocarbons and carbon monoxide and rate of reduction of nitrogen oxides. Oxygen sensors **28**, **30** sense the level of oxygen in the exhaust gas and communicate this information to the control circuit **22**. Based on this information, the control circuit **22** is programmed to actively control air and fuel flow to the engine **14** via the noted throttle **18** and fuel system **20**. Typically the control circuit **22** will control the throttle **18** and fuel system **20** to achieve a desired air-to-fuel ratio to thereby achieve optimum performance of the engine **14** and catalytic converter **26**.

The system **10** includes one or more oxygen sensors **28**, **30**, which can be located at different positions in the exhaust system **16**. In the particular example shown, the exhaust system **16** includes an inlet oxygen sensor **28** located upstream of the catalytic converter **26** and an outlet oxygen sensor **30** located downstream of the catalytic converter. The number and location of oxygen sensors **28**, **30** can vary. For example

the upstream oxygen sensor **28** can be entirely omitted. The inlet oxygen sensor **28** communicates with the control circuit **22** and measures the oxygen content of the exhaust gas entering the catalytic converter **26**. The outlet oxygen sensor **30** communicates with the control circuit **22** and measures the oxygen content of the exhaust gas exiting the catalytic converter **26**. The control circuit **22** controls air and fuel via the throttle **18** and fuel system **20** respectively based upon signals from the inlet and outlet oxygen sensors **28**, **30** such that a sufficient level of oxygen is present in the exhaust gas to initiate oxidation in the catalytic converter **26**.

Electric heaters **32**, **34** are provided for each of the respective oxygen sensors **28**, **30**. The heaters **32**, **34** are powered by a power source, such as for example the control circuit **22**. The control circuit **22** receives power from a battery **39**. The heaters **32**, **34** are configured to heat the sensors **28**, **30** to a desired operating temperature and are also configured to maintain the desired operating temperature throughout operation of the sensors **28**, **30**. The control circuit **22** powers the heaters **32**, **34** via the noted links.

Referring to FIG. **2**, the control circuit **22** is programmed to monitor an amount of current being drawn from the control circuit **22** by the respective heaters **32**, **34**. During normal operation of the sensors **32**, **34**, the amount of current being drawn by the heaters **32**, **34** will be substantially constant, as shown at linear segment A. If one of the sensors **28**, **30** malfunctions, the amount of current that is drawn by its respective heater **32**, **34** will dramatically increase, as shown at linear segment B. This occurs for example when the respective sensor **28**, **30** becomes wet via exposure to water in the exhaust system **16**. The control circuit **22** thus can identify that a sensor **28**, **30** has failed when the current draw of its respective heater **32**, **34** changes by a predetermined amount. Based on this information, the control circuit **22** is programmed to modify its control of the engine **14**. For example, the control circuit **22** can modify its control of the throttle **18** and/or fuel system **20** by disregarding signals received from an oxygen sensor **28**, **30** that is associated with a heater **32**, **34** having a change in current draw that exceeds the predetermined amount.

Thereafter, if the current drawn by the respective heater **32**, **34** reverts by a predetermined amount, such as back to the amount shown at linear segment A, the control circuit **22** can be programmed to again consider signals from the respective oxygen sensor **28**, **30** in its control of the engine **14**. This can occur for example where the sensor **28**, **30** dries out after being exposed to the water.

In the example shown, the system **10** also includes a display **36** for indicating to an operator when the current drawn by a heater **32**, **34** exceeds the predetermined amount. The control circuit **22** can be programmed to operate the display **36** when the noted current draw changes by the predetermined amount.

FIG. **3** depicts an exemplary method of controlling the marine engine **14**. At step **50**, a sensor is operated to sense a characteristic of exhaust gas emitted by the engine **14**. In this example, the sensor is an oxygen sensor **28**, **30** and the characteristic of exhaust gas is an amount of oxygen in the exhaust gas. At step **52**, the electric heaters **32**, **34** are operated to heat the sensors **28**, **30**. At step **54**, the amount of current drawn by the respective heaters **32**, **34** is monitored by the control circuit **22**. At step **56**, the control circuit **22** determines whether the amount of current drawn by the respective heater **32**, **34** has changed by a predetermined amount. If no, the control circuit repeats step **54**. If yes, the control circuit **22**, at step **58**, modifies its control of the engine **14**, for example by modifying its control of the throttle **18** and/or fuel system **20**. At step **60**, the control circuit **22** displays an alert on the display **36** to inform an operator that the respective sensor **28**, **30** is malfunctioning.

What is claimed is:

1. A control system for a marine engine emitting exhaust gas, the control system comprising:
- a sensor sensing a characteristic of the exhaust gas;
- an electrical heater heating the sensor; and
- a control circuit monitoring current drawn by the heater;
- wherein the control circuit controls an operational characteristic of the engine based upon the characteristic of the exhaust gas, and
- wherein the control circuit modifies its control of the operational characteristic of the engine when the current drawn by the heater changes by a predetermined amount.

2. The control system according to claim **1**, wherein the sensor comprises an oxygen sensor and wherein the characteristic of exhaust gas comprises an amount of oxygen in the exhaust gas.

3. The control system according to claim **1**, comprising a control circuit from which the current is drawn by the heater.

4. The control system according to claim **1**, wherein the control circuit modifies its control of the operational characteristic of the engine by disregarding the sensed characteristic of the exhaust gas.

5. The control system according to claim **1**, wherein the operational characteristic of the engine comprises an amount of fuel provided to the engine.

6. The control system according to claim **1**, wherein the operational characteristic comprises an amount of combustion air provided to the engine.

7. The control system according to claim **1**, comprising a display for providing an alert when the current drawn by the heater changes by a predetermined amount.

8. A method of controlling a marine engine, the method comprising:
- operating a sensor to sense a characteristic of exhaust gas emitted by the engine;
- operating an electrical heater to heat the sensor;
- monitoring an amount of current drawn by the heater;
- controlling an operational characteristic of the engine based upon the characteristic of the exhaust gas; and
- modifying said control of the operational characteristic of the engine when the current drawn by the heater changes by a predetermined amount.

9. The method according to claim **8**, wherein the sensor comprises an oxygen sensor and wherein the characteristic of exhaust gas comprises an amount of oxygen in the exhaust gas.

10. The method according to claim **8**, comprising modifying control of the operational characteristic of the engine by disregarding the sensed characteristic of the exhaust gas.

11. The method according to claim **8**, wherein the operational characteristic of the engine comprises an amount of fuel provided to the engine.

12. The method according to claim **8**, wherein the operational characteristic of the engine comprises an amount of combustion air provided to the engine.

13. The method according to claim **8**, comprising providing an alert when the current drawn by the heater changes by a predetermined amount.

14. A control system for a marine engine emitting exhaust gas via an exhaust conduit, the control system comprising:
- a sensor disposed at least partially in the exhaust conduit and sensing an amount of oxygen in the exhaust gas;
- an electrical heater heating the sensor; and

a control circuit in communication with the sensor and the heater, the control circuit monitoring current drawn by the heater and also controlling throttle of the engine based upon the amount of oxygen in the exhaust gas, and

wherein the control circuit modifies its control of throttle of the engine when the current drawn by the heater changes by a predetermined amount.

15. The control system according to claim **14**, wherein the sensor comprises an oxygen sensor and wherein the characteristic of exhaust gas comprises an amount of oxygen in the exhaust gas.

16. The control system according to claim **14**, comprising a control circuit from which the current is drawn by the heater.

17. The control system according to claim **14**, wherein the control circuit modifies its control of the operational characteristic of the engine by disregarding the sensed characteristic of the exhaust gas.

18. The control system according to claim **14**, wherein the operational characteristic of the engine comprises an amount of fuel provided to the engine.

19. The control system according to claim **14**, wherein the operational characteristic comprises an amount of combustion air provided to the engine.

20. The control system according to claim **14**, comprising a display for providing an alert when the current drawn by the heater changes by a predetermined amount.

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